ROLE OF INSECT POLLINATOR ON CUCUMBER (*CUCUMIS SATIVUS* L.) YIELD

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DECEMBER, 2016

ROLE OF INSECT POLLINATOR ON CUCUMBER (*CUCUMIS SATIVUS* L.) YIELD

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REG. NO.: 15-06939

A Thesis
submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: DECEMBER, 2016

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Dedicated to

My Beloved Parents

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CERTIFICATE

This is to certify that the thesis entitled, ***"ROLE OF INSECT POLLINATOR ON CUCUMBER (CUCUMIS SATIVUS L.) YIELD"*** *submitted to the Department of Entomology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S.) IN ENTOMOLOGY,*** *embodies the result of a piece of bonafide research work carried out by* ***FARZANA YEASMIN*** *bearing* **Registration No.15-06939** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institution elsewhere.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:
Place: Dhaka, Bangladesh

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ACKNOWLEDGEMENTS

The author wishes to acknowledge the immeasurable grace and profound kindness of the “**Almighty Allah**” the Most Gracious and The Supreme Rule of the universe for giving mental peace, health and strength to submit the thesis for the degree of Master of Science (MS) in Entomology.

The author would like to extend her heart-squeezed gratitude, deepest appreciation, best regards and indebtedness to her honorable teacher and research Supervisor **Prof. Dr. Mohammed Sakhawat Hossain,** Department of Entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, for her untiring guidance, scholastic supervision, valuable advice, innovative suggestions, constant encouragement, helpful comment, affectionate feeling and inspiration in all phases of conducting the research work and preparation of the thesis.

The author would like to express her sincere appreciation, heartfelt gratitude and immense indebtedness to her research Co-supervisor **Prof. Dr. Md. Mizanur Rahman ,**Department of Entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar Dhaka, for her kind cooperation, encouragement, affectionate feelings, technical help, valuable advice and helpful discussion throughout the entire period of research work and preparation of the thesis.

The author would like to express gratitude to, Professor, **Prof. Dr. Md. Mizanur Rahman**, Department of Entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar Dhaka. The author feels proud to express and boundless indebtedness to all the honorable course teachers.

Cheerful acknowledgements are expressed to her husband S.M. Zahidur Rahman who helped her with great support to prepare this thesis paper. The author would like to thank her friend Md. Arifur Rahman & Md.Mohiuddin fozlullah who gave technical support.

July, 2016 **The Author**

ROLE OF INSECT POLLINATOR ON CUCUMBER (*Cucumis sativus* L.) YIELD

ABSTRACT

Foraging activities of insect visitors were studied on cucumber *(Cucumis sativus L.)*. The insect visitors in decreasing order of abundance were *Formica sp. >Apis mellifera >Halictus sp. > Apis cerana>syrphids*. The activity of insects was peaked between 08.00-09.00 followed by 11.00-12.00 and 14.00-15.00 hours. The foraging behaviour of *A. mellifera and Halictus sp*. was studied. The bees spent significantly more time per flower during morning hours (sec/flower) and foraged significantly fewer flowers (7.9 flowers/min) compared to evening hours. There were significantly more nectar foragers (6.03/m²/10 min) than pollen foragers (5.16/m²/10 min). Most pollen foragers were observed during morning hours (6.59/m²/10 min) whereas nectar foragers were most active during noon hours (6.63/m²/10 min). Significant increase in fruit set was observed; highest being in hand pollination (70.68%) followed by open pollination (61.92%) and without honey bee pollination (48.96%). Percentage of misshapen fruits was maximum in without honey bee pollination (24.35%) followed by open pollination (20.25%) and hand pollination (14.1%). Without honey bee pollination resulted in significantly lowest percentage of healthy fruits (75.25%) as compared to hand (85.50%) and open pollination (79.64%). Similarly weight of fruits (770.51 g), number of seeds per fruit (390.56), fruit diameter (23.9 cm), fruit length (21.8 cm) and weight of 1000-seeds (23.14 g) was lowest in honey bee pollination as compared to hand pollination which was highest among the three form of pollination and that was fruits (985.13 g), number of seeds per fruit (425.22), fruit diameter (27.1 cm), fruit length (26.7 cm) and weight of 1000-seeds (28.64 g).

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LIST OF COMMONLY USED ABBREVIATION

FULL WORD	ABBREVIATION
And others	*et al.*
Bangladesh Bureau of Statistics	BBS
Bangladesh Agriculture and Research Institution	BARI
Cultivar	cv.
Degree Celcius	^{o}C
edest (means That is)	i.e.
Figure	Fig.
Gram	G
Micro gram	Mg
Micro mol	µM
Milligram/litre	mgL^{-1}
Namely	Viz.
Parts/million	Ppm
Percentage	%
Species (plural number)	spp.
Variety	var.

CHAPTER 1
INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the oldest vegetables that cultivated world-wide in tropical and subtropical parts of the world. Cucumber (*Cucumis sativus* L.) commonly known in Bengali as ‘Shosha’ is one of the most important vegetables belonging to family Cucurbitaceae consumed as a salad (Aran kumar *et al.*, 2011). It has tremendous economic and dietic importance. The total production of cucumber in Bangladesh was about 63000 metric tons in 23000 acres in the year 2015-2016 (BBS, 2016). The yield is very low compared to that of other developing countries. The potential yield of cucumber in our country is 15t/ha (Rashid, 1999). It is a good source of water, minerals, carbohydrates, protein, lipid, iron and vitamin in human diet (Rashid, 1999). Everyone is fond of eating this vegetable as raw for refreshment, especially as salad with fast food (Reshma, 2011).

Normally, cucumber plants are monoecious, produce both male and female flowers separately on the same plant. The male (staminate) flowers have very short stems and are borne in clusters of three to five. Whereas female (pistillate) flowers occur singly and can be recognized by the ovary at the base of the flower that develops into the fruit. Both male and female flowers produce nectar and most of the bee visitors collect nectar from it. The male flowers appear first and in considerably larger number than the female flowers. The male flowers usually appear 10 days before the first female flower appears (Judson, 1929). They normally outnumber the female flowers about 10 to 1 in ordinary monoecious variety (Alex, 1957a). During 1970's a revolution occurred in cucumber production with the introduction of gynoecious varieties which bear predominantly female flowers and provide uniform crop suitable for one single machine harvest (Lord, 1985). Pollen for gynoecious varieties is provided by monoecious plants cultivated alongside them.

Cucumber is an important commercial crop and economic success of cucumbers depends upon large yields of quality fruits. The fruits are mainly used for pickles and salads. Many factors influence the yield and quality of cucumber crop. One of the most important considerations is successful pollination. Adequate pollination usually assures uniform and perfectly formed fruits with even maturity (McGregor, 1976). Uniform and perfectly formed fruits are necessary in commercial production of cucumber and thereby bring good market price to the producers.

Due to the presence of separate male and female flowers, it requires some external agents for successful pollination. The cucumber flowers are not wind or self-pollinated and mainly insects are the major pollinators of cucumber flower especially honey bees (Connor and Martin, 1969). The presence of large sticky pollen grains further demonstrates the need of active transfer of pollen between flowers (Sedgley and Scholefield, 1980). Since the plant typically produce small amount of pollen, pollinators are needed for efficient pollen transfer from one flower to other to have good fruit set. Predominantly gynoecious (female flowering) cucumbers grown for machine harvest are in particular need of an abundant pollinator force because of the high density of planting (50,000-250,000 plants/ha) (Motes, 1977; Van, 1993).

The flower of cucumber remain open only for a single day, if they are not pollinated during that time the flower abort and drop from the vine. When pollination occurs but is incomplete, fruit do not develop properly (Hodges and Baxendale, 1991). Inadequate pollination results in small or misshapen fruit and low yield of marketable fruits. Therefore, keeping in view the pollination requirements of cucumber, the present investigations were carried out to know the role of insect pollinator on the fruit set and quality of cucumber.

The present investigations have been designed with following objectives.

i) To identify various types of insect visitors and their abundance in cucumber flowers.

ii) To study the effect of pollination on fruit yield of cucumber.

CHAPTER II
REVIEW OF LITERATURE

Cucumber is a leading commercial crop grown widely throughout the tropical & sub-tropical parts of the world. Many factors influence the yield and quality of cucumber crop. One of the most important considerations is successful pollination. It is a well-documented fact that cucumber requires insect pollination to set fruit. Insect visitors of cucumber are numerous but not all of them are important pollinators. Of all the insect visitors mainly honey bees are major pollinators of cucumber (Connor and Martin, 1969; Woyke & Brownikowska, 1984). Development of distinct male (staminate) and female (pistillate) lines in recent years has accentuated the need for honey bee pollination (Lord, 1985).

Honey bees adopt their foraging behavior according to the floral structure of the crop and factors like corolla shape, color and its attractiveness, rewards as pollen or nectar or both, concentration and amount of nectar etc. The literature relevant to the present studies is reviewed under the following headings.

2.1 Relative abundance of insect visitors

Many insect species visit cucumber flowers but, honey bee is the primary and only dependable pollinator of cucumbers. Tsyganov (1953) considered one bee equal in value to 11,000 thrips as pollinators of cucumber. McGregor and Todd (1952) observed other insects (e.g. native bees, thrips and ladybird beetles) on the flowers, but found their activity was not conducive to pollination and obtained no evidence that they contributed to fruit set. Skrebtsova (1964) stated that honey bees are the only pollinators present in many U.S. fields and represent 84 to 96 percent of insect pollinators on cucumber. Grewal and Sidhu (1978) observed the insect visitors of cucumber in Punjab and found that *Apis* *florea, A. dorsata, A. mellifera* and solitary bees, were main visitors of the crop.

Kauffeld *et al*. (1978) collected insects from cucumbers, which belonged to 37 species (29 were identified). Honey bees collecting nectar were the most numerous visitors, and few of them carried pollen. Cervancia and Bergonia (1991) observed that most common visitors of cucumber were *Xylocopa chlorina, Xylocopa philippinensis, Megachile atrata* and *Apis dorsata*. They were most abundant from 10.00-11.00 h. Sajjanar *et al.* (2004) found that a total of 24 species of insects visited the cucumber flowers in which hymenoptera were predominating. Among honey bees, A. dorsata was the most frequent visitor. Rana *et al.* (2005) found that main visitors of cucumber were small ants (15.7), followed by *A. mellifera* (4.32), bumble bees (3.34), *A. cerana* (1.8), Nomia (0.96) and syrphids (0.78).

Brett and Sulivan (1972) observed several species of solitary bees, visiting the flowers of *Citrullus lanatus*, watermelon but it was observed that the honey bees were the principal pollinators. Njoroge *et al.* (2004) studied pollination ecology in *Citrullus lanatus*, which is a species vulnerable to pollination loss and observed that this species depends heavily on the honey bees (*A. mellifera*) for pollination. Other pollinators identified include Xylocopa bees, Halictid bees, Hypotrigona bees, flies and beetles.

Jaycox *et al.* (1975) observed, honey bees, black solitary bees, or bumble bees visiting pumpkin (*Cucurbita moschata*) flowers. *A. florea* and *A. dorsata* were the most abundant bees visiting *Cucurbita pepo*, solitary bees belonging to the

Anthophoridae, Xylocopidae, Megachilidae and Halictidae were also present (Grewal and Sidhu, 1978). *Apis spp* were also found to be the most important pollinators of *Cucurbita pepo* in Bangalore, India (Girish, 1981); the relative proportion of *A. cerana, A. dorsata* and *A.florea* present were 87:10:3, respectively, the number of solitary bees was negligible. Avila *et al.* (1989) studied the time of effective pollination in fields producing hybrid seed of squash (*Cucurbita pepo* var.me/opepo) and observed that *A. mellifera* was the most abundant insect pollinator in the morning, followed by *Trigona spinipes* and *Chrysomelid Diabrotica speciosa*.

Grewal and Sidhu (1978) reported that honey bees *A. florea* and solitary bees of Halictidae were the most abundant bee visitors (65 and 23%, respectively) of muskmelon in Punjab. Rao and Suryanarayana (1988) found that *A. cerana* comprised 87% of the pollinating insects of watermelon; the others included *A. florea* and *Trigona iridipennis*. Malerbo *et al.* (1999) reported that most frequent insects on watermelon flowers were ants (37.2%), followed by stingless bees *Melloons sp*. (32%), *Trigona sp.* (9%), flies (9%), Beetles (77%) and Butterflies (5.1%).

Insects such as ants, thrips, beetles and solitary bees have been identified as possible pollinators of cucurbits but, it is generally recognized that honey bees (*A. mellifera*) were the most important pollinators in commercial crop production (Free,1993). Rust *et al.* (2003) collected 6 families, 15 genera and 43 species of bees on *Ecballium elaterium* (cucurbitaceae). Numerically dominant species were *Lasioglossum malachurum*, *A. mellifera* and *Ceratina cyanea*.

2.2 Foraging behaviour of insect visitors

2.2.1 Proportion of nectar and pollen foragers

McGregor and Todd (1952) observed that pollen and nectar collection in cantaloupe by the honey bees, both in cages and outside usually began as soon as the flowers opened. Pollen collection reached a peak by about 11 a.m. and tapered off rapidly after midday with little collection after 2 p.m. Nectar collection also reached a peak about 11 a.m. and tapered off much less rapidly with some activity as late as 6 p.m.

Shemetkov (1960) in Russia and Amaral *et al.* (1963) in Brazil reported that bees collected cucumber pollen heavily from 8 to 10 a.m. and nectar from 10 a.m. to noon. Bees collected pollen on cucumber in early morning and switched to nectar later in morning. Few honey bees collected pollen from cucumber flowers and that also in small loads. Nectar was the prime attractant (Collision and Martin, 1975). Pollen foraging in Maryland, USA was highest before 10 a.m. and decreased dramatically in the afternoon (Tew and Carron, 1988).

Sajjanar *et al.* (2004) observed that under caged conditions, pollen foragers of *A. cerana* initiated activity by 0600 h. The activity was at a peak (6 bees/m^2/5 min) by 10.00h and then declined gradually till 18.00 h whereas, nectar foragers initiated activity by 7.00 h remained in low number initially but picked up activity by noon to attain a peak by 13.00 h at 6.89 bees/m^2/5 min followed by gradual decrease in activity.

A. cerana, *A. florea* and *Melipona spp*. started collecting watermelon pollen from 8.30 h and reached a peak in numbers on the crop at 10.30 h (Bhambure, 1958). The watermelon flowers were fully opened by 7.00 h and most were fully closed by 14.00 h. Peak pollen collection occurred at 9.00 h and decreased thereafter (Rao and Suryanarayana, 1988).

Sanduleac (1959) found that cultivars of *Cucurbita maxima*, *C. pepo* and *C. moschata* were worked intensively by bees from 06.00 to 12.00 h daily and the numbers of bees reached a peak between 08.00 and 09.00 h, the male flowers were preferred to female flowers indicating that they were collecting pollen deliberately. Hernandez and Lemus (1999) observed that honey bee activity on pumpkin was greatest from 9.00 to 10.00 h foraging both for nectar and pollen.

2.2.2 Floral preference of honey bees

Amaral *et al.* (1963) concluded that bees show no preference for staminate over pistillate flowers in cucumber. Connor (1969) and Martin (1970) stated that even when honey bees visit staminate flowers, the primary objectives is to collect nectar and that cucumbers are visited for pollen largely when other sources of pollen are absent. Stephan (1970) also reported that bees get very little pollen from cucumber.

Honey bees showed a significant preference for pistillate flowers in *Cucurbita pepo* which increased the chance of pollination. *Peponapis pruinosa* preferred staminate flowers. However, *P. pruinus* worked the flowers more rapidly than honey bees (Tepedino, 1981). Rust *et al.* (2003) observed that most visits (97%) on *Ecballium elaterium* were to staminate flowers. Observation of foraging by honey bees (*Apis mellifera*) showed that they began to visit *Cucurbita pepo* flowers as soon as they opened with a foraging peak at 7.00-9.00 h, male flowers were visited first, but female flowers received more visits (Nepi *et al.,* 1996)

2.2.3 Foraging rate and foraging speed.

In U.S.A. honey bee foraging increased rapidly from 8 a.m. to peak activity at midday then sharply fell to low levels by 4 p.m. Most activity was confirmed between 10 a.m. and 2 p.m. (Connor and Martin, 1970). In USA most honey bees visits to cucumber crops occurred between 9.00 and 16.00 h with a peak between 11.00 and 12.00 and a secondary peak between 14.00 and 15.00 (Kauffeld and Williams, 1972; Collision and Martin; 1979). The first visit a flower received after opening was of longer duration than later visits; thereafter the time per flower visit tended to decrease during the day, reflecting the amount of nectar present, with a mean of 11.4 sec (Connor et ai., 1975).

Rapp (1981) reported that honey bees started foraging on cucumber flowers at about 6.00 h and activity was highest from 9.00 to 12.00 h then it decreased early in the afternoon. The frequency of bee visits to pistillate was lower than to staminate, but the duration of visit was longer in pistillate (8 to 16 second), than on staminate (4 to 10 seconds). Cervancia and Bergonia (1991) observed high activity of pollinators from 10.0-11.00 h. They concluded that pollinators were most active when nectar secretion was highest. The lesser the time spent by a bee per flower, the greater its chance to pollinate more flowers. Honey bee began to visit the flowers soon after they opened and were most numerous on fields between 8.00 h and 10.00 h; thereafter, they became steadily fewer until the flowers had closed (Goff, 1937; Adlerz, 1966). The duration of bee visits was different on male and female flowers. In 441 observations made in 1959, the longest single visit to a female flower was 20 sec and the mean visitation time was 5.7 sec. In 1003 observations on female and 989 observations on male flower made in 1960, the longest visits were 60 and 27 sec, and the mean visitation times were 8.0 and 5.7 sec, respectively, (Adlerz,1966). The time *A. cerana* pollen foragers spent per flower of watermelon, increased from 1-4 sec at 8.00 h to 8.2 sec at 12.00 h. The time spent in collecting nectar from a flower was less for staminate than pistillate flowers (Rao and Suryanarayana, 1988).

Girish (1981) reported that there was very little difference in the time spent by bees in collecting nectar from pistillate and staminate flowers of *Cucurbita pepo*. However, the time spent tended to decrease from the time of the flower opening to closer. The time spent by a bee collecting nectar varied widely; the average time for female was 70 sec and for male 65 sec. The average time spent by pollen collectors on male flowers. In 441 observations made in 1959, the longest single visit to a female flower was 20 sec and the mean visitation time was 5.7 sec. In 1003 observations on female and 989 observations on male flower made in 1960, the longest visits were 60 and 27 sec, and the mean visitation times were 8.0 and 5.7 sec, respectively, (Adlerz,1966). The time *A.*

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Girish (1981) reported that there was very little difference in the time spent by bees in collecting nectar from pistillate and staminate flowers of *Cucurbita pepo*. However, the time spent tended to decrease from the time of the flower opening to closer. The time spent by a bee collecting nectar varied widely; the average time for female was 70 sec and for male 65 sec. The average time spent by pollen collectors on male was 14 sec (Couto *et al.*, 1990). It was observed that 67% of foraging bees visited flowers between 9.00 — 11.00 h, reaching a maximum at 10.00h. Each bee visited an average of 6.1 staminate and 2.3 hermaphrodite flowers per minute between 9.00 and 10.00 h (Chen, 1996).

Stanghellini *et al.* (2002) compared the activities of bumble bees and honey bees (*A. mellifera*) on field grown cucumber and watermelon and observed that bumble bees started foraging activity 15-40 minutes before *A. mellifera*; both species continued foraging until flowers closed in early afternoon. *B. impatiens* consistently visited more flowers per minute. Rana *et al.* (2006) observed that there was no varietal significant difference in number of cucumber flowers visited per minute or foraging time per flower by honey bee, *A. mellifera*. However, in the morning hours the bees spent significantly more time (10.95 sec) and visited less number (3.95 sec) of flowers as compared to noon and evening hours.

2.3 Amount of nectar sugar in cucumber flowers

McGregor and Todd (1952) observed that the melon flowers opened between 7 and 8 a.m. and nectar secretion began at once. About 3 milligrams of nectar was produced by 11 a.m. after which secretion apparently ceased in the staminate flower. In the hermaphroditic flower secretion continued up to the afternoon, a total of 18 milligrams being produced. Shuel (1961) observed that nectar secretion in flowers is influenced by the maturation of stigma and stamens and also often by the age of flowers and is usually greater on the first day after the flower is open than later. The age and condition of flower also have an important effect on the secretion of nectar.

Collision (1973) found that in cucumber, *Cucumis sativus* L. maximum secretion occurred on the day of anthesis. Most flowers secreted no nectar on the second day. When male and female flowers occur on the same plant, one kind may secrete more nectar than other. Female flowers secreted more nectar than male flowers. Nemirovich-Denchenko (1964) reported that the average daily nectar yield of female and male flowers was 1.29 and 0.69 mg, respectively, and was greatest 3-4 h after opening. Kaziev and Seidova (1965) found that a female cucumber flower secreted between 1.1 and 2.4 mg of nectar compared to between 0.9 and 1.6 mg by a male flower, the amount secreted depending to some extent upon the cultivar and environmental conditions. Kropacova and Nedbalova (1974) observed that on an average a bee visited 4-5 blossoms/min and a flower was visited on average 28 times. The average sugar content in nectar was 2.3 mg/flower/day.

Kamler and Tronickova (1982) in Czechoslovakia found significant differences in nectar production between different monoecious cultivars of cucumber which on an average yielded 1.36 mg sugar per flower per day; in contrast flowers of gynoecious cultivars only 0.57 mg sugar per day. The average sugar content in cucumber nectar was 57.6±3.3 mg/flower.

Nepi *et al.* (1996) studied the nectary structure, nectar secretion, composition and insect visits in flowers of *Cucurbita pepo* cv. *Greyzini* in which anthesis lasts for only 6 hours. The nectar of female flowers were more abundant and richer in sugars and proteins than that of male flowers and was therefore more attractive to insect visitors. Flowers whose nectar was collected by bees fell the day after anthesis; unvisited flower fell after 3 days. Couto *et al*.(1990) reported that the ratio of male (M) to female (F), *Cucurbita pepo* flowers was over 7, but F produced 2.5 times more nectar and its sugar content was more than twice that of M nectar.

Nectar traits were compared between male and female flowers of *Cucurbita maxima* to determine any difference in the characteristics of the main reward offered to pollinators. Nectar chemical composition and sugar proportion were similar between flower types. Total nectar sugar production per female flower was threefold higher than per male flower and nectar removal did not have any effect on total nectar production in both flower morphs (Ashworth and Galetto, 2002).

2.4 Pollination requirements

Tarbaeva (1960) reported that melon stigma was more receptive for pollination 3-4 hours after anthesis. Nandpuri and Brar (1966) observed that in case of muskmelon maximum stigma receptivity prevailed 2 hours before anthesis and 2-3 hours after anthesis. Safarajan (1966) studied the effect of the age of stigma on fertilization in watermelon and obtained highest fruit set (37-44%) when newly opened flowers were pollinated between 7-8 a.m. both in intra varietal pollinations. He further observed that for getting maximum fruit set fresh pollen should be used.

Shakti *et al.* (1990) observed that anthesis in cucumber started at 5 a.m. and was complete by 8 a.m. with the maximum anthesis occurring between 6 and 7 a.m. The maximum anther dehiscence and stigma receptivity also occurred between 6 and 7 a.m. Stigmas become receptive 12 h after anthesis and remained so 24 h after opening of flowers at moderate temperature (Singh *et al.* 2004). The flowers of cucumber remained open only for one day. If they were not pollinated at that time the flowers aborted and dropped from the plants. When pollination occurred but was not complete fruit did not develop properly (Hodges and Baxendale, 1991). Connor (1969) found that the best time of the day for effective cucumber pollination in Michigan was from 10 a.m. to 3 p.m. He also found that pollination was about equally effective when the pollen was placed on one or all the stigma lobes.

Pollination was adversely affected by high temperature and low humidity. Pollination after dehiscence up to 08.00 h was stated to be most effective (Seshadri, 1986). Pollination even after 24 h were found effective in greenhouse conditions and no differences were found in seed set between flowers pollinated on the day of anthesis or those pollinated the following day (Munger, 1988). AI-Fattah (1991) observed that foraging activity of honey bees (*A. mellifera*) was affected by the prevailing environmental conditions which also affected nectar secretion by squash plants and its concentration. It was concluded that each squash plant require at least 1 honey bee visit during the optimum pollination time (06.00-09.00 h).

Fruit and seed set in insect pollinated agricultural crops rely primarily on honey bees because of their ease in management and transportation. Gingras et aL (1997) observed that honey bees (*Apis mellifera*) were almost only pollinator to visit cucumber flowers in open pollinated plots in Quebec (Canada) and found that open pollinated plotsproduced significantly more fruits with superior weight and pollination rates than caged plots. Seyman *et al.* (1969) reported the importance of honey bees in cucumber production by obtaining increased fruit yield with increased exposure to bee activity. Introductions of honey bee colonies were recommended where populations of native insect pollinators were low (Cervancia and Bergonia, 1991).

In many fruit and vegetable crops the number of bee visitation can be the limiting step in obtaining optimal yield (Wolf *et al.*, 1999). Shemetkov (1957) reported that the number of visits a flower received influenced the number of seeds and weight of fruit produced in cucumber; thus 2-8 visits per flower gave fruits of 221 g average weight and 60 seeds, and 50 visits per flower gave 500 g fruits with 140 seeds. Adlerz (1966) observed that *A. mellifera* visits were minimum for normal fruit development in cucumber.

Jaycox *et al.* (1975) found that as the number of bee visits increased from 1 to 12, the percent of fruit set in pumpkin increased from 6.5 to 64.5, or about a tenfold difference. The mean number of seeds and mean weight of the pumpkin also increased. Honey bee activity in commercial pickling cucumber fields should provide each flower on the day of anthesis with 15 to 20 flower visits, to achieve maximum fruit set for machine harvesting. A significant positive correlation was obtained between daily per cent fruit set and amount of pollen being distributed with each bee visit (Collision and Martin, 1978).

Collision (1976) and Stanghellini *et al.* (1997) have demonstrated that pistillate (female) cucumber flowers require 12 or more honey bee visits to set marketable fruit. Gingras *et al.* (1999) observed that a single visit to a cucumber flower was sufficient, but flower that had the greatest number of visits and highest cumulative duration of visit also had the greatest cucumber yields. Prakash *et al.* (2004) also studied the effect of number of bee visits on fruit set and some fruit characters of cucumber and observed that a minimum of 10 bee visits are necessary to minimize the flower drop and increase fruit set rate and a minimum of 20 bee visits to get more fruit weight, fruit volume and number of seeds per fruit.

Musiiko (1941) indicated that hand pollination in cucumber using a small brush with a head of cotton at the end gave 30-35 per cent higher fruit set. Tuljzenkova (1955) showed that glass house grown cucumbers when pollinated by bees, produced higher yield and better quality fruits than those produced by hand pollination. Stambera (1962) observed that in open set, bees were the excellent pollinators and increased yield and quality of cucumber seeds. Steinhauer (1970) reported that honey bees increased cucumber yield by 39 percent as compared to the fields where bee activity lacked. Sevgican (1976) pointed out that hand pollination in cucumber resulted in earliness and improved fruit quality. Robinson and Hefferman (1980) stated that maximum seed set was obtained when pollen was applied generously to whole stigmatic surface. Kauffeld *et al.* (1975) obtained increased quantity and quality of cucumber (*Cucumis sativus* L.) fruits with honey bees in caged vs. field studies.

Woyke and Brownikowska (1984) observed that the number of honey bees on fields where hives had been introduced was from 1.5 to 5.0 times as high as on fields without hives; on the later fields honey bees constituted between 23 and 81% of total insects. Significant correlation coefficients were found between cucumber yield and the number of honey bees foraging on the flowers.

Alex (1957 b) reported that the calculated average yield of three plots in a cucumber field caged without honey bees, three plots caged with honey bees and three plots not caged was 80, 409 and 472 kg, respectively. He attributed the set in the cages without honey bees to pollination by small ground nesting solitary bees. Similar results were obtained by the Canadian Department of Agriculture (1961). The mean yield, calculated in kilograms per hectare, during five years of a plot, caged without honey bees, a plot caged with honey bees and a plot not caged were 1754, 4683 and 5787 respectively. Kauffeld and Williams (1972) in Wisconsin, USA, found that plots of cucumbers caged with honey bees yielded a mean of 64 kg fruit compared to only 15 kg of misshapen fruit in a plot caged without bees.

Cervancia and Bergonia (1991) observed that in the cucumber plants caged with honey bees, caged to exclude bees and uncaged treatment the fruit set were 75, 33 and 58%, respectively; the mean fruit weights were 0.87, 0.36, 0.60 kg, and mean numbers of filled seeds per fruit were 203, 51 and 134. The introduction of honey bee colonies to cucumber is recommended when the populations of native insect pollinators are low.

Rafiq (1992) recorded the number of pistillate and staminate flowers, fruit set and fruit weight in 30 plants of cucumber, 15 of these plants were covered with muslin cloth to prevent pollination by honey bees while the remaining plants were left exposed. Fruit weights were greater (2.69 kg/plant.) for honey bee pollinated plants than for self-pollinated ones (2.03 kg/plant).

Prakash *et al.* (2004) recorded significantly higher fruit weight (1210 g), number of seeds per fruit (482) and fruit volume (1315 ml) in cucumber (*Cucumis sativus*) with 20 bee visits compared to 15 bee visits which resulted in 1110 g fruit weight, 1205 ml fruit volume and 448 seeds per fruit. A minimum of 10 bee visits are necessary to minimize fruit drop and increase fruit set rate and a minimum of 20 bees visit to get more fruit weight, fruit volume and number of seeds per fruit.

Mann (1953) found that in muskmelon (*Cucumis melo* L.) open pollinated flowers produced large fruits and had more seeds than hand pollinated flowers. Awasthi (1969) reported 98 percent and 68 percent fruit set in Kakri (*Cucumis melo*) following natural pollination and hand pollination, respectively. Sakamori *et al.* (1977) while working on muskmelon found no difference in fruit size and quality following open pollination and hand pollination, respectively.

McGregor and Todd (1952) observed that from the plots caged to exclude bees only 4 marketable melons were obtained from 160 plants. On similar plots caged with bees 180 marketable melons were produced. This highly significant difference established the necessity of bees in commercial melon production.

In Australia, Williams (1987) found that plots (2 x3 m) of melons caged to exclude bees, caged with honey bees and not caged yielded 20,26 and 27 melons, respectively, with a mean weight of 0.68, 1.11 and 1.10 kg each and total weights of 13.4, 28.5 and 29.4 kg per plot.

Gaye *et al.* (1991) observed that honey bees advanced the initial harvest date and early yield of muskmelon crop. Individual fruit weight also increased and was highly correlated with total seed weight. In greenhouses in Japan, honey bee pollination of muskmelons was as effective as hand pollination; attaining up to 98% fruit set, and was more economical (Sakamori *et al.* 1977).

In Belgium, Lemasson (1987) compared the yield of melons grown in glasshouses with and without honey bees. The presence of honey bees increased the fruit set, 18.5 : 2.5 %; the weight of fruit per plant, 2664 :1469 g the weight per fruit, 621 :491 g, and the mean number of fruits per plant, 43 : 29. Garcia *et al.* (1998) evaluated the effects of no pollination, manual pollination and pollination by *A. mellifera* in green house trial with netted melons and observed that percentage of fruit drop was greater in non-pollinated plants than in pollinated plants. Bee pollination resulted in the highest fruit and seed weights (711.51 and 21.28 g, respectively); these were significantly higher than in manually pollinated plants (622.38 and 15.79). Fruit diameter, average number of seeds/fruit and thickness were similar in manually and bee-pollinated plants.

Dasgan of at (1999) studied comparative behavior of honey bees and bumble bees in pollination of melon (*Cucumis melo L.*) and found that the yields obtained from honey bee pollinated and bumble bee pollinated melon plants were similar. Sarehane (1994) observed that melons open to pollination by bees had higher sugar concentrations and were firmer than those isolated from bees.

Kato and Couto (2002) studied the importance of insect pollination in melon. Some flowers were bagged to prevent insect visitation and others were left open. There was no fruit production in the covered treatments, and it was evident that honey bees are important and effective pollinators of melons for fruit production (quality and quantity).

Adlerz (1960) observed no difference in fruit set in water melon from hand pollination and open pollination methods. He further observed that fruit set was directly correlated with length of ovary (12mm -31mm). It was reported that fruit set and yield after hand pollination in watermelon was comparable with that of open pollination. He recorded higher fruit set (32.3%) from pollination between 8-9 am followed by pollination at 9-10a.m. (25.97%) and positive correlation between melon weight and number of seeds per fruit.

Nath and Vashistha (1969) studied fruit set and fruit development in watermelon (*Citrullus lanatus*) and observed better fruit set (60.6-75%) from open pollination followed by hand pollination (50-66.6%).

Obhayashi (1976) recorded no difference in fruit set and yield of water melon plants pollinated by hand and those open pollinated. There was 10% more fruit set on the plots where honey bee colonies were placed than control plots caged to exclude bees (Mouzin *et al.*, 1980).

Rao and Suryanarayana (1988) found no fruit in 4x8m plots of *C. lanatus* caged without insect pollinators; a mean of 31.5 fruits of 4.3 kg mean weight were produced in cages with *A. cerana* colonies; and a mean of 22.8 fruits of 3.9 kg mean weight were produced in plots not caged.

Heemert *et al.* (1987) obtained a mean yield of 13 fruits/plant, which was the same as that produced by hand pollination in a 9 week trial. In a second trial lasting 18 weeks, bee pollination resulted in 53.4 fruits/plants and hand pollination 56.9 fruits/plants. The weight of fruits and the weight and number of mature seeds / melon were significantly higher from plots visited by bees than from those where bees were excluded (Brewer, 1974).

Stanghellini *et al.* (1998) compared bumble bees (*Bombus impatiens*) and honey bees (*A. mellifera*) at 4 visitation levels to pistillate flowers of watermelon. Bee visitation had a strong weight were produced in cages with *A. cerana* colonies; and a mean of 22.8 fruits of 3.9 kg mean weight were produced in plots not caged.

Heemert *et al.* (1987) obtained a mean yield of 13 fruits/plant, which was the same as that produced by hand pollination in a 9 week trial. In a second trial lasting 18 weeks, bee pollination resulted in 53.4 fruits/plants and hand pollination 56.9 fruits/plants. The weight of fruits and the weight and number of mature seeds / melon were significantly higher from plots visited by bees than from those where bees were excluded (Brewer, 1974). Stanghellini *et al.* (1998) compared bumble bees (*Bombus impatiens*) and honey bees (*A. mellifera*) at 4 visitation levels to pistillate flowers of watermelon. Bee visitation had a strong positive influence on seed set. All flowers which were bagged to prevent insect visitation aborted suggesting the need for active pollen transfer between staminate and pistillate watermelon flowers. When compared at equal bee visitation levels, flowers visited by *Bombus impatiens* consistently contained more seeds than those visited by *A. mellifera*.

Williams (1987) observed that mean total weight of melon from plots caged to exclude bees was 13.4 kg which was significantly lower than the plots caged with honey bee (mean 28.5 kg) or from plots in open fields provided with 1 honey bee colony / acre (29.4 kg) and total number of melons obtained were 20, 26 and 27, respectively. Mean fruit weights were 0.68, 1.11 and 1.10 kg.

Hernandez and Lemus (1999) observed higher pumpkin yield (weight /ha) in plots nearest to hives, which gradually decreased as the distance from the hive increased.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, 23°41′N latitude and 90°22′E longitude with an elevation of 8.6 meter above sea level (Figure 1). The experiments were carried out during 2017. The material used and methodology adopted for these experiments are described as follow:

3.1 Raising of crop

The planting was done in a plot size of 3.75m X 2.74m at a distance of 0.5m x 0.5m with six plants of each treatment; three on each side of the plot. Three plants per treatment of each replication were checked. Good cucumber seeds were taken from the seed shop and soaked in water for 24 hours. Seedlings were raised in polythene bags and seedlings were planted as per spacing in the evening for reducing settlement stress. Cowdung, ash and water hyacinth were given in every pit at the rate of 5-6 kg and each pit was supplied with 100 gm TSP and 60-70 gm MP fertilizer with a fixed supplement of 50 gm urea after every 15 days. Irrigation and weeding was maintained as per necessity.

3.2 Treatments and Design

Cucumber (*Cucumis sativus L.)* was used with 3 treatments (Without bee pollination, Hand pollination, and Open pollination) in this study. The experiment was laid out in Randomized Block Design (RBD) during the year 2017 in eight replications.

3.3 The insect material, data collection and identification

Insect visitors on cucumber flowers were collected by usual cone type hand net. Sweeps were made throughout the blooming of cucumber at 08.00-09.00, 11.00-12.00 and 14.00-15.00, 17.00-18.00, 20.00-21.00 hours of the day. Insects were then killed in pure benzene and preserved as dry specimen.

Insect collection was started after three days of commencement of flowering and continued till 90 percent of flowering was over. Collected insects were identified by comparing them with the identified species maintained in the Department of Entomology, SAU.

3.4 Relative abundance of insect visitors

For relative abundance of insect visitors, plants were selected randomly in three different plots and observations were started 2-3 days after the flowering. These observations were taken between 08.00-09.00, 11.00-12.00 and 14.00-15.00, 17.00-18.00, 20.00-21.00 hours of the days and were continued for 7 sunny days.

3.5 Foraging behavior of bees

Major bee visitors associated with pollination of cucumber with different foraging behavior were recorded in three different plots as follows: The number of *A. mellifera* bees foraging for pollen or nectar was recorded in one meter square bloom area per ten minutes during 08.00-09.00, 11.00-12.00 and 14.00-15.00 hours of the day. In total 18 observations were made during 6 days of observation.

3.6 Studies on the kind of pollination

3.6.1 Without bee pollination

The cucumber plants in 3 selected plots were caged in 40 mesh nylon net and no bees were allowed to get in the net.

3.6.2 Open pollination

The selected cucumber plots were left open for the access of insect pollinators.

3.6.3 Hand pollination

The male and female flowers of selected plants were bagged with butter paper bag one day prior to anthesis. Afterwards, when anthesis took place, butter paper bags were opened and petals of male flower were removed. Pollen from bagged male flowers was dusted over the female flowers by gently rubbing the anthers on the stigma; then again the flowers were bagged for 2-3 days to avoid any contamination by foreign pollen. After 3-4 days of pollination, bags were removed.

3.7 Effect of different modes of pollination on fruit and seed characters

3.7.1 Total fruit set, crooked fruits and healthy fruits

To find out the effect of different modes of pollination on fruit set, crooked fruits and healthy fruits, six plants of each treatment, three on each side of the plot.three plants per treatment of each replication was checked.

The percentage fruit set was calculated by dividing the number of fruits formed

$$\text{Fruit set \%} = \frac{\text{Total no. of fruit set/vine}}{\text{Total number of female flowers/vine}} \times 100$$

Similarly the percentage of crooked and healthy fruits was worked out.

$$\text{Crooked fruit \%} = \frac{\text{Total no. of crooked fruits/vine}}{\text{Total number of fruits/vine}} \times 100$$

$$\text{Healthy fruit \%} = \frac{\text{Total no. of healthy fruits/vine}}{\text{Total number of fruits/vine}} \times 100$$

in each treatment over total number of female flowers and then multiplying the value by 100.

3.7.2 Fruit weight

To calculate fruit weight in different modes of pollination 5 fruits were selected randomly from each treatment and replicated thrice and average fruit weight was recorded.

3.7.3 Fruit length

The polar length of selected five fruits was recorded in cm and mean values were worked out.

3.7.4 Fruit width

The fruit width in the middle was measured in cm on selected five fruits and mean values were worked out.

3.7.5 Number of seeds per fruit

After recording fruit length and fruit breadth the seeds were extracted from individual fruit separately to count the number of seeds per fruit and mean values were worked out.

3.7.6 1000-seed weight

Five representative samples of 1000-seeds were taken from each treatment to determine the average test weight in grams.

3.8 Statistical analysis

The data were statistically analyzed using randomized block design after proper transformation where ever needed (Gomez and Gomez, 1986). Graphical data representation, ANOVA, Multiple Range Test, Fisher’s LSD and the P value calculated by STATGRAPHICS Centurion XV.I for better understanding.

CHAPTER-4

RESULT & DISCUSTION

The results obtained during the investigations carried on "Studies on the role of insect pollination in cucumber yield" are presented in this chapter.

4.1 Bloom visiting insects and their relative abundance on cucumber crop

4.1.1 Insect visitors of cucumber bloom

There were different types of insect species which visited the cucumber flowers during blooming, listed in Table 1. In total 11 insect species belonging to 11 genera under 7 families were recorded visiting the cucumber bloom during study. Out of these, 2 to Diptera, 4 to Coleoptera and 6 species belonged to Hymenoptera.

Among these, most frequent visitors were: *Apis mellifera*, *Formica sp.*, *Halictus sp.*; *Apis cerana* was frequent visitor whereas *Syrphid* was less frequent visitors.

4.1.2 Relative abundance of insect visitors on cucumber bloom

Data on the relative abundance of insect visitors during different hours of the day is presented in Table 2. During 08:00-09:00 hrs, *Formica sp.* were significantly most abundant (14.94 ants/m^2/10min) followed by *A. mellifera* (3.46 bees/m^2/10min) and *B. haemorrhoidalis* (3.32 bees/m^2/10min). The latter two species showed similarity with each other in respect of abundance.

Table 1. Insect visitors of cucumber bloom with their frequency of occurrence

Sl. No.	**Common Name**	**Scientific Name**	**Family**	**Order**	**Frequency of visits**
1	F. Indian Honey bee	*Apis cerana* F.	Apidae	Hymenoptera	**
2	Rock bee	*A. dorsata* F.	Apidae	Hymenoptera	*
3	Italian Honey bee	*A. mellifera* L.	Apidae	Hymenoptera	***
4	Little honey bee	*Apis florae*	Apidae	Hymenoptera	*
5	Ants	*Formica sp.*	Formicidae	Hymenoptera	***
6	Solitary bee	*Halictus sp.*	Halictidae	Hymenoptera	***
7	syrphid fly	*Episyrphus balteatus* (DeGeer)	Syrphidae	Diptera	**
8	syrphid fly	*Scaeva pyrastri* L.	Syrphidae	Diptera	*
9	Red pumpkin beetle	*Aulacophora foveicollis* L.	Chrysomelidae	Coleoptera	*
10	Spotted cucumber beetle	*Diabrotica undecimpunctata* Mann	Chrysomelidae	Coleoptera	**
11	Ladybird beetle	*Coccinella septempunctata* L.	Coccinellidae	Coleoptera	*
12	Blister beetle	*Mylabris pustulate* T.	Meloidae	Coleoptera	*

*=Less frequent visitors
**=Frequent visitor
***=Most frequent visitors

Syrphids were least abundant (0.56 flies/m^2/10min) followed by *A. cerana* (1.18 bees/m^2/10min), other pollinators (1.27 insects/m^2/10min) and *Halictus sp.* (1.7 bees/m^2/10min) which were statistically similar with each other. During 11.00-12.00 hrs, Formica sp. were most abundant (13.6 ants/m^2/10 min) followed by *A. mellifera* (2.70 bees/m^2/10 min), the latter two species were statistically at par with each other. *Syrphids* were least abundant (0.51 flies/m^2/10 min) followed by other insects (1.08 insects/m^2/10 min), *A. cerana* (1.13 bees/m^2/10 min) and *Halictus sp.* (1.56 bees/m^2/10 min) which were statistically at par with each other.

During 14.00-15.00 hrs, *Formica sp.* were most abundant (9.96 ants/m^2/10min) followed by *A. mellifera* (1.86 bees/m^2/10 min), the latter two species were statistically at par with each other. *Syrphids* were least abundant (0.53 flies/m^2/10 min) but were statistically at par with *A. cerana* (0.62 bees/m^2/10 min), other insects (0.68 insects/m^2/10 min) and *Halictus sp* (0.96 bees/m^2/10 min).

During 17.00-18.00 hrs, *Formica sp.* were most abundant (7.71 ants/m^2/10min) followed by *A. mellifera* (0.93 bees/m^2/10 min), the latter two species were statistically same. *Syrphids* were least abundant (0.36 flies/m^2/10 min) but were statistically at par with *A. cerana* (0.27 bees/m^2/10 min) and other insects (0.27 insects/m^2/10 min).

During 20.00-21.00 hrs, other insects mostly beetles were abundant (0.33 ants/m^2/10min) followed by some *Formica sp.* (0.2 bees/m^2/10 min).

Table 2. Relative abundance of insect visitors per 10 minutes per m^2

Sl. No	Species	08.00 - 09.00 hrs	11.00-12.00 hrs	14.00-15.00 hrs	17.00-18.00 hrs	20.00-21.00 hrs	Mean	Standard Deviation (SD)	Coeff. of Variation (CV)
1	*A. cerana*	1.18	1.13	0.62	0.27	0	0.64	0.51927	81.14%
2	*A. mellifera*	3.46	2.7	1.86	0.93	0	1.79	1.26678	75.58%
3	*A. dorsata*	3.32	2.22	1.91	0.93	0	1.676	0.44388	61.14%
4	A. florea	1.27	1.08	0.68	0.27	0.33	0.726	1.37528	76.83%
5	*Formica sp.*	14.94	13.6	9.96	7.71	0.2	9.282	5.83249	62.84%
6	*Halictus sp.*	1.7	1.56	0.96	0.52	0	0.948	0.71099	75.00%
7	*Syrphids*	0.56	0.51	0.53	0.36	0	0.392	0.23231	59.26%
Mean		3.775	3.257	2.36	1.57	0.075	2.207	**F-Ratio**	**9.09**
								P-Value	**0.0000**

The data on the abundance of insect visitors irrespective of the day hours showed that *Formica sp*. were most frequent visitors (9.28 ants/m^2/10 min). *A. mellifera*(1.79 bees/m^2/10 min) was statistically at par with each other followed by *Hatictus sp*. (0.95 bees/m^2/10 min). *Syrphids* were least abundant (0.39 flies/m^2/10 min) but were statistically at par with *A. cerana* (0.64 bees/m^2/10 min) and other insects (0.73 insects/m^2/10 min).

Activity of insect visitors during different hours of the day showed that their abundance was significantly higher during 08.00-09.00 hrs, with an average of 3.78 insects/m^2/10 min, followed by 11.00-12.00 hrs (3.26 insects/m^2/10 min) and 14.00-15.00 hrs (2.36 insects/ m^2/10 min). But at 17.00-18.00 hrs (1.57

insects/m^2/10 min) and at night that rate were decreased ie. 20.00-21.00 hrs (0.08 insects/m^2/10 min) which were significantly different from each other.

The ANOVA table decomposes the variance of the data into two components: a between-group component and a within-group component. The F-ratio, which in this case equals 9.08742 (see Table 2), is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a statistically significant difference between the means of the 7 variables at the 95.0% confidence level. Multiple range tests were applied to know the statistical significant difference between relative abundances of species. *Formica sp.* showed highest significant difference in relative abundance than all other species. The table applies a multiple comparison procedure to determine which means are significantly different from which others. The bottom half of the output shows the estimated difference between each pair of means. An asterisk has been placed next to 6 pairs, indicating that these pairs show statistically significant differences at the 95.0% confidence level. The method currently being used to discriminate among the means is Fisher's least significant difference (LSD) procedure. With this method, there is a 5.0% risk of calling each pair of means significantly different when the actual difference equals 0. (See appendix 1).

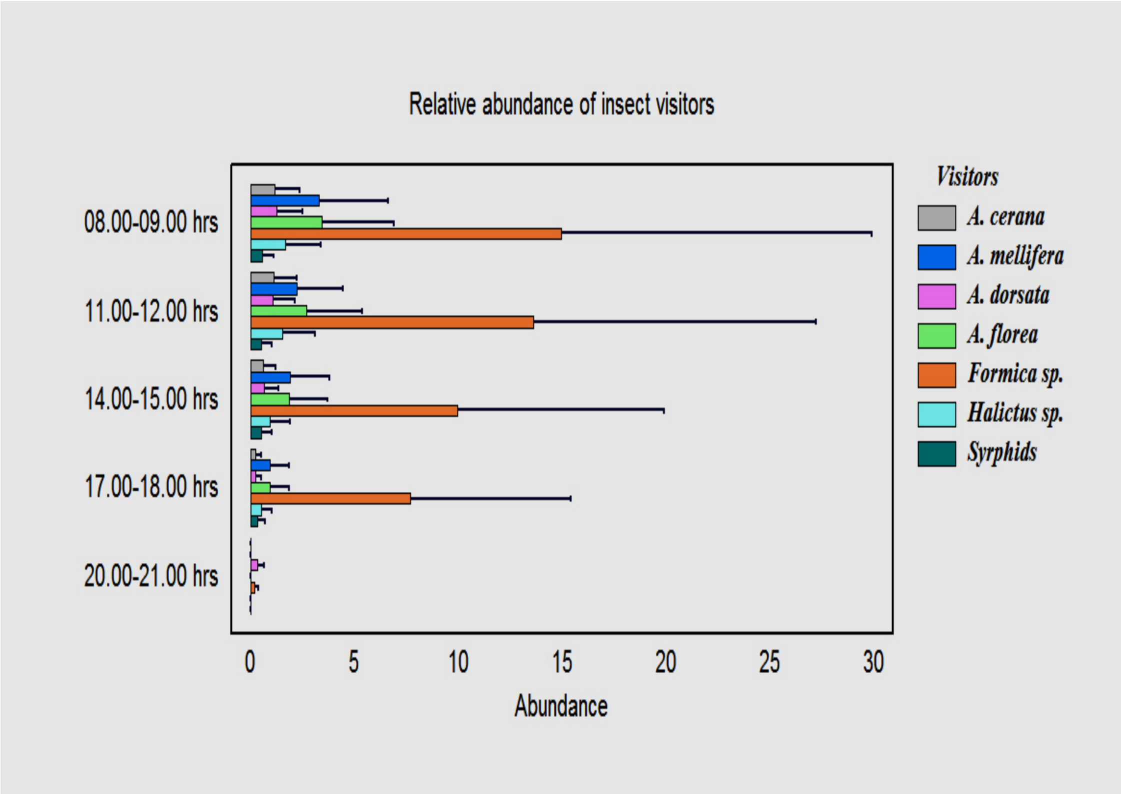

Figure 01. Relative abundance of insect visitors per 10 minutes per m^2

Illustration expressing the variations of relative abundance of different insect visitors on Cucumber flower at the study period. *Formica sp.* showed the highest relative abundance in all five hours of study. (Figure 01)

Hourly relative abundance of insect visitors per 10 minute per m^2 also shown in a graphical analysis below for clearer observation:

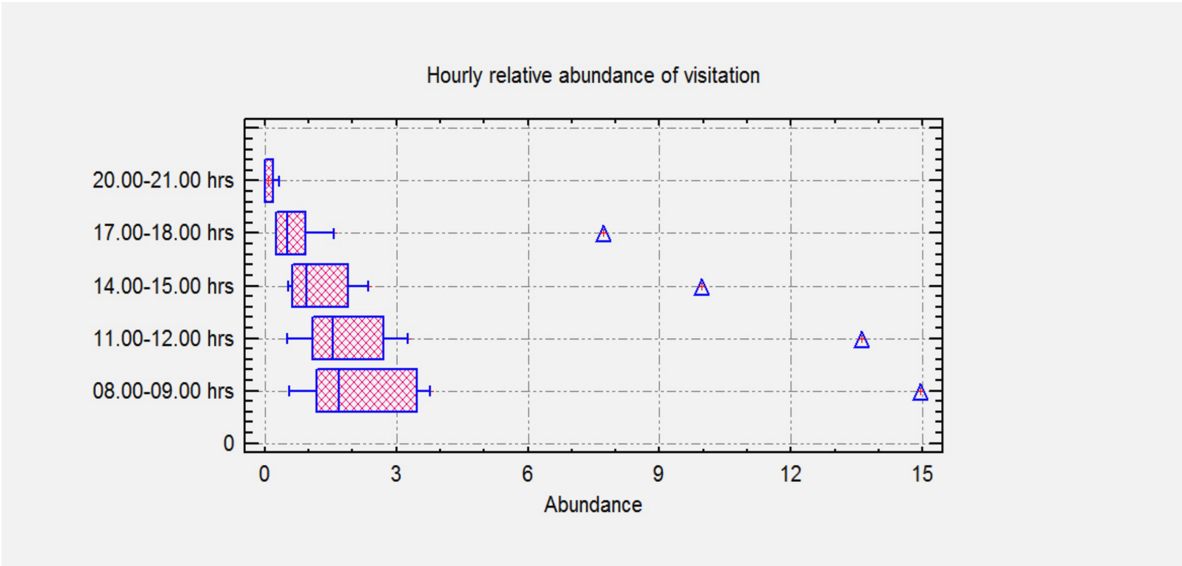

Figure 02. Hourly relative abundance of visitation.

Figure 02 represents highest abundance of visitation of all insects at 08.00-09.00 hour.

4.2 Foraging behavior of bee pollinators

4.2.1 Proportion of pollen or nectar foragers of *Apis mellifera*

Data on the proportion of nectar or pollen foragers of *A. mellifera* bees at different hours of the day on the cucumber bloom is presented in Table 3. It is revealed that irrespective of the day hours there were more number of nectar foragers with an average of 6.03 bees/m^2/10 min as compared to pollen foragers (5.16 bees/m^2/10 min) and the difference was statistically significant.

During 08.00-09.00 hrs, the average numbers of pollen foragers (6.59 bees/m^2/10 min) were significantly higher than nectar foragers (5.62 bees/m^2/10 min).

During 11.00-12.00 hrs, the average numbers of nectar foragers (6.63 bees/m^2/10 min) were significantly higher than pollen foragers (4.88 bees/m^2/10 min).

During 14.00-15.00 hrs, the average number of nectar foragers were significantly higher (5.85 bees/m^2/10 min) than pollen foragers (4.0 bees/m^2/10 min) and differed statistically from each other.

The data in Table 3 reveals that irrespective of the day hours, there were a significantly higher number of nectar foragers (6.03 bees/m^2/10 min) than pollen foragers (5.16 bees/m^2/10 min). Similar results have also been observed by several other workers (Kauffeld and Williams 1972; Collison and Martin 1975; Collision and Martin 1979). The average numbers of pollen foragers were significantly higher during 08:00-09:00 (6.59 bees/m^2/10 min) whereas there were significantly more nectar foragers during 11:00-12:00 (6.63 bees/m^2/10 min). Sajjanar *et al.* (2004), Bhambure (1958) and Rao and Suryanarayana (1988) also reported the pollen foraging to be maximum during morning hours and nectar foraging to be maximum during afternoon in cucurbit flowers.

The average numbers of nectar or pollen foragers were significantly higher during 08.00-09.00 (6.11 bees/m^2/10 min) and 11.00-12.00 (5.76 bees/m^2/10 min) followed by 14.00-15.00 (4.92 bees/m^2/10 min). This might be correlated with the abundance of insect visitors which was higher during morning hours.

Table 3. Proportion of *Apis mellifera* bees foraging for pollen or nectar per 10 minutes per m^2 cucumber bloom at different hours.

Day hours	Pollen	Nectar	Mean
08.00-09.00 hrs	6.59	5.62	6.105
11.00-12.00 hrs	4.88	6.63	5.755
14.00-15.00 hrs	4	5.85	4.925
Mean	5.16	6.03	

$CD_{0.05}$
Foragers 0.32
Day hours 0.39
Day hours x foragers 0.56

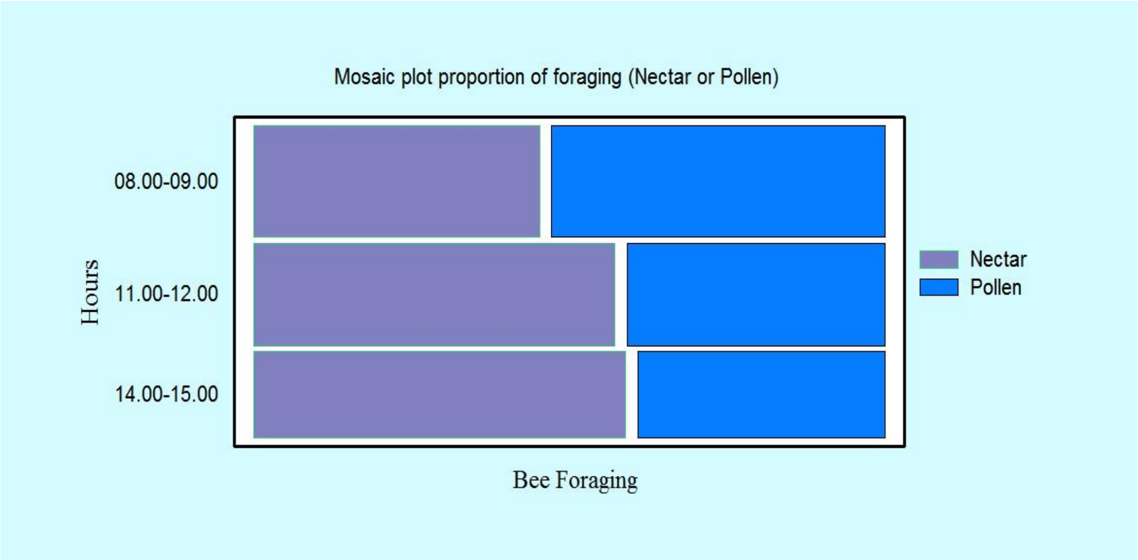

Figure 03. Mosaic plot showing proportion of *Apis mellifera* bees foraging for pollen or nectar per 10 minutes per m^2 cucumber bloom at different hours.

Mosaic plot expressing that in the morning 08.00-09.00 hours was efficient for pollen collection and 11.00-12.00 and 14.00-15.00 hours were efficient for nectar collection.

4.3 Effect of different modes of pollination on fruit set, crooked fruits and healthy fruits

Data on percentage of fruit set, crooked fruits and healthy fruits are presented in Table 4, 5 and 6 respectively.

4.3.1 Fruit set

The data presented in Table 4 revealed that the percent of fruit set was significantly at par in hand pollination (70.68%) and open pollination (62.09%)and higher than without honey bee pollination (48.96%)

4.3.2 Healthy fruits

The data (Table 4, Figure 4) showed that irrespective of lines, the percentage of healthy fruits was maximum in hand pollination (85.50%) followed by open pollination (79.64 %)and minimum percentage of healthy fruits was observed in without honey bee pollination (75.25%) and all of them were statistically different from each other.

Among different modes of pollination the fruit set (Table 4, Figure 4) was observed to be significantly higher in hand polination, HP (70.68%) and open pollination, OP (61.92%) as compared towithout bee pollination, WBP (48.96%). This may be due to the reason that in hand pollination pollen is applied generously to whole stigmatic surface. Mouzin *et al.* (1980), Lemasson

(1987), Cervancia and Bergonia (1991) and Rafiq (1992) also obtained higher percentage of fruit set in BP as compared to OP. So in absence of bee there were lack of pollination. The fruits obtained from OP (20.25%) and HP (14.1%) was also found to be better with respect to shape since the percentage of misshapen fruits was highest in WBP (24.35%). Therefore, the percentage of well-formed healthy fruits was highest in HP (85.5%) followed by OP (79.64%) and WBP (75.25%), in accordance with the results of Cervancia and Bergonia (1991), Hernandez *et al.* (1999), and Kato and Couto (2002), which might be attributed to sufficient amount of pollen being received by the flowers in HP and BP treatment.

Table 4. Effect of different modes of pollination on percent fruit set, crooked and healthy fruits

Mode of pollination	Fruit set (%)	Misshapen fruits (%)	Healthy fruits (%)
Without Honeybee	48.96	24.35	75.25
Open	61.92	20.25	79.64
Hand	70.68	14.1	85.5
$CD_{0.05}$	0.98	0.76	0.69

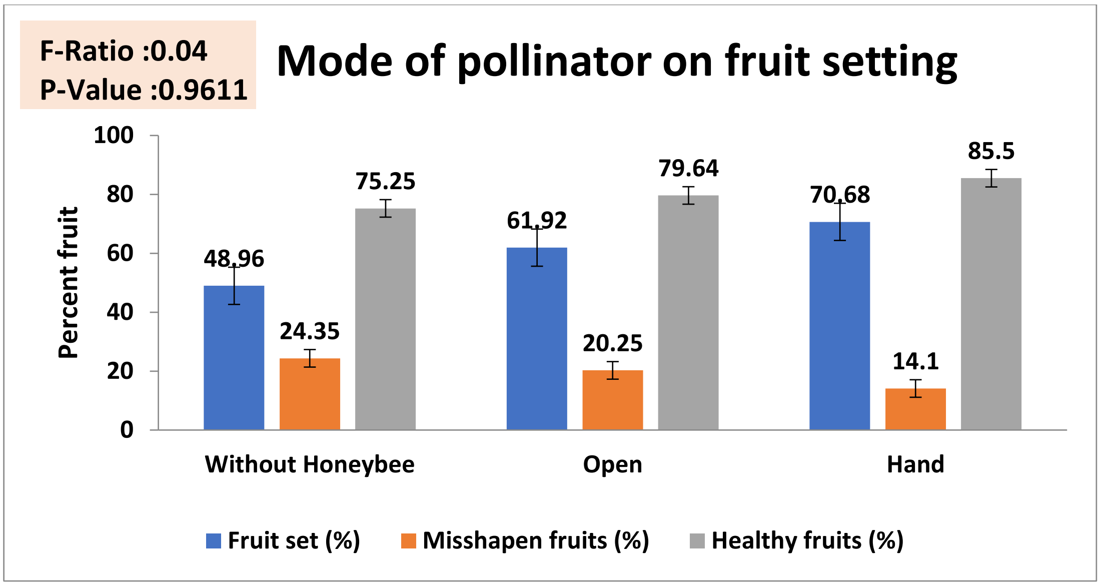

Fig 04: Effect of different modes of pollination on percent fruit set, crooked and healthy fruits.

The F-ratio, which in this case equals 0.0399833, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is greater than or equal to 0.05, there is not a statistically significant difference between the means of the 3 variables at the 95.0% confidence level.

4.4 Effect of different modes of pollination on fruit weight, number of seeds/fruit and fruit size (cm) in cucumber at the time of seed harvesting

4.4.1 Fruit weight

Data presented in Table 5 showed that the weight of fruit was maximum in hand pollination (985.13 g) which was statistically at par with open pollination(977.87 g) and minimum in without bee pollination (770.51 g) the latter being statistically at par with hand pollination (990.2 g)

4.4.2 Number of seeds/fruit

The maximum number of seeds per fruit were observed in hand pollination (425.22 seeds/fruit) and minimum in without bee pollination (390.56 seeds/fruit), the latter being statistically at par with open pollination (403.43 seeds/fruit) (Table 5).

4.4.3 Fruit diameter (cm)

The data presented in Table 6 showed that the fruit diameter was found to be maximum in hand pollination with an average of (27.1 cm/fruit) followed by open pollination (26.8 cm/fruit) which is statistically non-significant whereas minimum fruit diameter was found in without bee pollination (23.9 cm/fruit).

4.4.4 Fruit length (cm)

The fruit length was found to be maximum in hand pollination (26.7 cm/fruit) followed by open pollination (26.5 cm/fruit) and minimum fruit diameter was found inwithout bee polllination (21.8 cm/fruit).

4.5 Weight of 1000-seeds in different treatments

Data presented in Table 6 showed that the weight of seeds was significantly higher in hand pollination (28.64 g) followed by open pollination (27.73 g) and without bee pollination (27.73 g).

The fruit characteristics such as fruit weight (985.13.g), number of seeds per fruit (425.22), fruit diameter (27.1cm) and fruit length (26.7cm) was found to be significantly higher in hand pollinated plants whreas minimum fruit weight

(770.51cm), number of seeds per fruit (390.56cm), fruit diameter (23.9cm), fruit length (21.8cm) and 1000-seed weight (23.14 cm) was found in without bee pollination **(Tables 5, Figure 5).** But Brewer (1974), Garcia *et al.* (1998) and Prakash *et al.* (2004) had found that the number of seeds per fruit and larger fruit size in bee pollinated plants might be attributed to the sufficient number of pollen grains received by the flowers which were best provided by honey bees in caged conditions as compared to OP and HP. This also might be due to the adequate pollination done by honey bees inside the cage whereas this study obtained the lowest value in yield in case of without bee pollination.

Table 5. Effect of different modes of pollination on fruit weight and number of seeds/fruit at the time of seed harvesting.

Mode of Pollination	**Weight of fruit (g)**	**No. of seed/fruit**
Without Honeybee	770.51	390.56
Open	977.87	403.43
Hand	985.13	425.22
$CD_{0.05}$	47.65	27.93

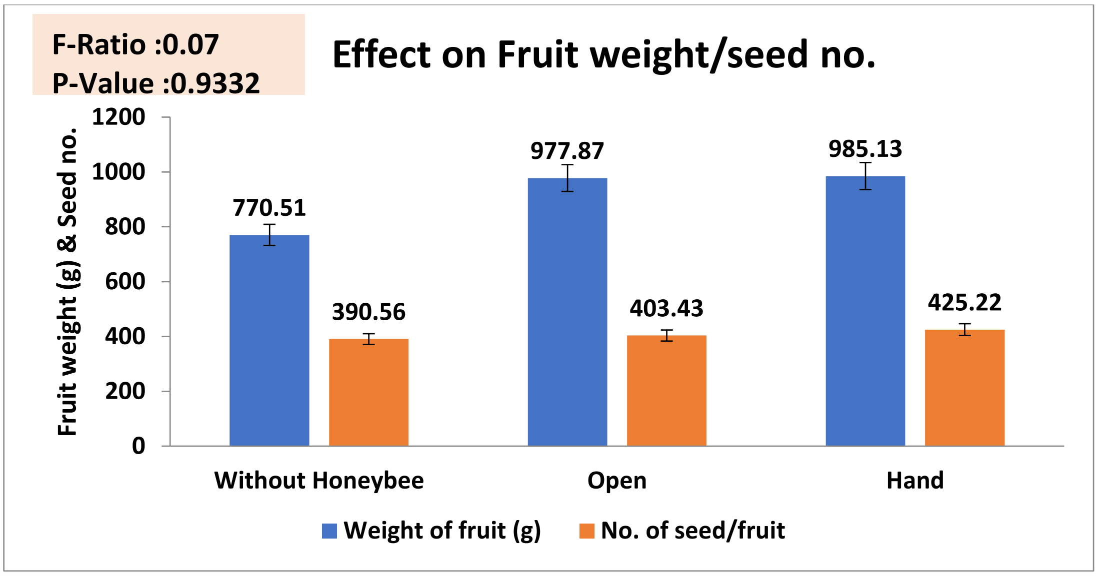

Fig 05: Effect of different modes of pollination on fruit weight and number of seeds/fruit at the time of seed harvesting.

The F-ratio, which in this case equals 0.0707538, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is greater than or equal to 0.05, there is not a statistically significant difference between the means of the 3 variables at the 95.0% confidence level.

Table 6. Effect of different modes of pollination on fruit size (cm) and 1000-seed weight.

Mode of pollination	Fruit diameter (cm)	Fruit length (cm)	1000-seed weight (g)
Without Honeybee	23.9	21.8	23.14
Open	26.8	26.5	27.73
Hand	27.1	26.7	28.64
$CD_{0.05}$	0.82	0.63	0.91

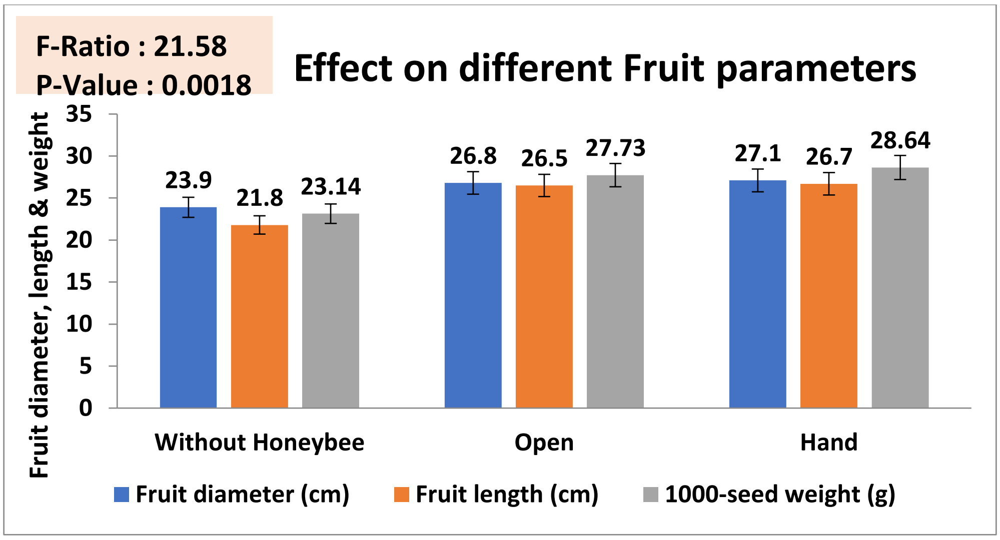

Fig 06: Effect of different modes of pollination on fruit size (cm) and 1000-seed weight.

The F-ratio, which in this case equals 21.5837, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a statistically significant difference between the means of the 3 variables at the 95.0% confidence level.

The table applies a multiple comparison procedure to determine which means are significantly different from which others. The bottom half of the output shows the estimated difference between each pair of means. An asterisk has been placed next to 2 pairs, indicating that these pairs show statistically significant differences at the 95.0% confidence level. (See appendix 2)

CHAPTER V

SUMMERY AND CONCLUSION

The present investigations on "Role of insect pollination in cucumber yield" were undertaken to determine the various insect visitors of cucumber, their relative abundance, foraging behavior of major bee pollinators and effect of different modes of pollination on fruit and seed characters. The salient findings are summarized below: In total twelve insect species were recorded that visited the cucumber bloom, out of which *Formica sp.* (9.24) were most abundant followed by *Apis mellifera* (1.79), *Halictus sp.* (0.95), and *A. cerana* (0.64). *Syrphids* (0.39) were least abundant. Activity of insect visitors was at peak in between morning (3.78) followed by noon (3.26) and evening (2.36). Least activity was recorded at night 20.00-21.00 (.08).

The results on proportion of pollen or nectar foragers of *A. mellifera* revealed that there was significantly more number of nectar foragers (6.03/m^2/10min) as compared to pollen foragers (5.16/m^2/10min). The pollen foragers were highest during morning hours (6.59/m^2/10min) whereas the nectar foragers were maximum during noon hours (6.63/m^2/10min).

Among the different modes of pollination the fruit set was the highest in hand pollination (70.68%) and minimum in without bee pollination (48.96%). The percentage of crooked fruits was the highest in WBP (24.35%) and minimum in hand pollination (14.1%) whereas the percentage of healthy fruits was the highest in hand pollination (85.5%) and minimum in without bee pollination (75.25%). The fruit weight (985.13g), number of seeds per fruit (425.22), fruit diameter (27.1cm) and fruit length (26.7cm) were maximum in hand pollination as compared to open and without bee pollination. The weight of 1000-seeds was also maximum in hand pollination (28.64g) as compared to other modes of pollination.

Since without bee pollination exhibits the lowest fruit set, healthy fruits, fruit weight, fruit size, number of seeds per fruit and weight hence we know Bee Pollination (*A. millifera*) resulted in higher fruit set, healthy fruits, fruit weight, fruit size, number of seeds per fruit and weight. So in absence of bee pollinator hand pollination could be considered the best

CHAPTER VI

REFERENCE

Adegas, J. E. B. and Nogueira, C. R. H. (1992). Entomophilous pollination in rape (Brasssica napus L. var. oleifera) in Brazil. Apidologie 23: 203-209.

Adlerz, W. C. (1960). Pollination of watermelon by honey bees Report of Florida Agriculture Experimental Station, pp 345-346.

Adlerz, W. C. (1966). Honey bee visit numbers and watermelon pollination. *Econ. J. Entomol*., **59**(1): 28-31.

Alex, A. H. (1957a). Honey bees aid pollination of cucumbers and cantaloupes. Texas Agricultural Experimental Station Progress Report, U.S.A., 1936, 4p.

Alex, A. H. (1957b). Pollination of some crops by honey bees. Texas Agricultural Experimental Station Progress Report, U.S.A., No. 1960.

Al-Fattah M. A. A. (1991). Behaviour of honey bee foragers and their influence as pollinators on summer squash flowers (*Cucurbita pepo* L.). Bulletin of Faculty of Agriculture, University of Cairo **42** (4): 1169-1186.

Amaral, E., Mitidieri, J. and Vencousky, R. (1963). Studies on the activities of *Apis mellifera* L. while visiting the flowers of *Cucumis sativus* L. *Olericultura*(Brazil), **3**: 181-193.

Anonymous. (1961). Effects of honey bees on cucumber production. Canadian Department of Agriculture, Charlottetown Experimental Farm P.E.I. Research Report 17, 1958-1961.

Anonymous. (2002). FAO Bulletin of Statistics, Rome, Italy

Anonymous. (2006). Department of Agriculture, H.P., Shimla-5.

Arunkumar, K.H., Patil, M.G., Hanchinamani, C.N., Goud, I.S., Hiremath, S.V. (2011). Genetic relationshipof growth and development traits with fruit yield in F2 population of BGDL × Hot season of cucumber (*Cucumis sativus* L.). *Karnataka J. Agric. Sci***. 24**: 497-500.

Ashworth, L. and Galetto, L. (2002). Differential nectar production between male and female flowers in a wild cucurbit, *Cucurbita maxima sp*. andreana (*Cucubitaceae*). *Canadian J. Bot*. **80** (11): 12031 208

Avila, C. J., Martinho, M. R. and Lima, J. O. G. De. (1989). Time of effective pollination in fields producing hybrid seed of squash (*Cucurbita pepo* var. melopepo). *Anais da sociedade Entomologica do Brasil* **18**: 23-32

Awasthi, D. N. (1969). Pollen viability fruit set and fruit development studies in kakri (*Cucumis melo L.* var. utilissimus Dutch). *Plant Science*.**1**: 57-59.

Batra, S. W. T. (1967). Crop pollination and flower relationship of the wild bees of Ludhiana, India (*Hymenoptera*:*Apoidae*). *Kansas J. Ento. Soc.***40** (2): 164-177.

BBS. (2016). Yearbook of Agricultural Statistics-2016, May 2017. Bangladesh Bureau of Statistics (BBS). Statistics and Informatics Division (SID). Ministry of Planning, Government of the People's Republic of Bangladesh. p.41.

Brett, C. H. and Sulivan, M. J. (1972). Bee attraction to cucurbit flowers and pollination. Bulletin of North Carolina Experimental Station, No. 443,19p.

Brewer, J. W. (1974). Pollination requirement for watermelon seed production. *Apic. J. Res.* 13 (3): 207-212.

Celli, G. and Giordani, G. (1981). lmportanza economica e biological dell'ape (*Apis mellifera* L.) per la fruttificazione del melone (*Cucumis melo L.*). In: Collura protetta Bollettino dell' Istituto di Entomologia dell Universta di Bologna. 13: 91-114.

Cervancia, C. R. and Bergonia, E. A. (1991). Insect pollination of cucumber (*Cucumis sativus* L.) in the Philippines. *Ada Hort.* **288**: 278-282.

Chen, C. T. (1996). Effects of honey bees on pollination and fruit set of cantaloupe. *Chinese J. Ento.***16** (1): 25-33.

Collison, C. H. (1973). Nectar secretion and how it affects the activity of honey bee in the pollination of hybrid pickling cucumber, *Cucumis sativus* L., M.Sc. Thesis, Michigan State University, U.S.A.

Collision, C. H. (1976). The interrelationship of honey bee activity, foraging behaviour, climatic conditions and flowering in the pollination of pickling cucumbers, *Cucumis sativus* L., Ph.D. Thesis, Michigan State University, U.S.A., 268p.

Collision, C. H. and Martin, E. C. (1975). A scanning electron microscope study of cucumber (*Cucumis sativus)* nectaries. *Apic. J. Res.***14**: 79-84.

Collision, C. H. and Martin, E. C. (1978). The relationship of foraging activity to fruit set and shape in the pollination of pickling cucumbers, *Cucumis sativus* L. Proceedings of the Fourth International Symposium on Pollination, Maryland. 183-188.

Collision, C. H. and Martin, E. C. (1979). Behaviour of honey bees foraging on male and female flowers of *Cucumis sativus*, *Apic. J. Res.***18**:184-190.

Connor, L. J. (1969). Honey bee pollination requirements of hybrid cucumber, *Cucumis sativus* L. *American J. Bee*.**114**(14), 457.

Connor, L. J. and Martin, E. C. (1969). Honey bee pollination of cucumbers. *American J. Bee.* 109: 389.

Connor, L. J. and Martin, E. C. (1970). The effect of delayed pollination on yield of cucumbers grown for machine harvest. *American Soc. J. Hort. Sci*. **95**(4): 456-458 .

Connor, L. J., Collison, C. H. and Martin, E. C. (1975). The pollination of hybrid cucumbers by honey bees: research from 1967 to 1973. In: Proceedings of the 3rd International Symposium on pollination, 1974, pp 165-174.

Corbet, S. A. (1978). Bee visits and nectar of *Echium vulgare* L. and *Sinapsis alba* L., *Ecol. Entomol.* **3**: 25-77.

Corbet, S. A. (1979). Humidity nectar and insect visits to flowers with special reference to Crataegus, Tilia and Echium. *Ecol. Entomol.* **4**: 9-22.

Couto, R. H. N. and Calmona, I. C. (1993). Insect pollination of cucumber (*Cucumis sativus* L.). *Naturalia*. **18**: 77-82.

Couto, R. H. N., Pereira, J. M. S. and Couto, L. A. (1990). Effects of pollination in *Cucurbita pepo*. *Cientifica.***18**(1): 21-27.

Currence, T. M. (1932). Nodal sequence of flower type in the cucumber. Proceedings of *American Soc. Hort. Sci.***29**: 477-479.

Dasgan, H. Y., Ozdogan, A. O., Abak, K. and Kaftanoglu, O. (1999). Comparison of honey bees (*Apis mellifera*) and bumble bees *(Bombus terrestris)* as pollinators for melon (*Cucumis melo L.*) grown in greenhouses. *Acta Hort.***492**: 131-133

Free, J. B. (1993). Insect pollination of crops, edn. U. K. Academic Press, London, 544p.

Garcia, R. C., Resende, F. V., Marcosa, A. A., Toloi, D. P., Faleiros, J. A. G., Turquino, R. P. and Souza, S. De. (1998). Study of melon (*Cucumis melo*) pollination by *Apis mellifera* in the greenhouse. *UNIMAR Ciencias* **7**(2): 123-131

Gingras, S., Oliveira, D. De. and Gingras, J. (1997). Honey bees and the production of cucumbers in Quebec (Canada). *Acta Hort.* **437**: 395-397

Gingras, S., Gingras, J. and Oliveira, D. De. (1999). Visits of honey bees (Hymenoptera: Apidae) and their effects on cucumber yields in the field. *Econ. J. Entomol.* **9**(2): 435-438.

Girish, P. P. (1981). Role of bees in pollination of summer squash (*Cucurbita pepo* L.) with special reference to *Apis cerana* F. (Hymenoptera: Apidae). M.Sc. thesis, University of Agricultural Sciences, Bangalore.

Goff, C. C. (1937). Importance of bees in the production of watermelon. *Florida Entomologist.* **2**: 30-31.

Gomez, K. A. and Gomez, A. A. (1986). Statistical procedure for agricultural research. 3rd edn. John Willey and Sons, New York, U.K. 680p.

Grewal, G. S. and Sidhu, G. (1978). Insect pollination of some cucurbits in Punjab. Indian Agric. J. Sci.**48**: 79-83.

Heemert, C. V., Smeekens, C., Ruijter, A. De. (1987). Pollination of zucchini (Courgettes) in greenhouses by honey bees. *Apidologie*. **18**(4): 341-343.

Hernandez, S. J. C. and Lemus, I. (1999). Yearly output in pumpkin using the honey bee (*Apis mellifera*) as pollinating insect. Apiacta **34**(4): 104-106.

Hodges, L. and Baxendale, F. (1991). Bee pollination of cucurbit crops. Report of University of Nebraska Lincoln Cooperative Extension, NF91-50

Jaycox, E. R., Guynn, G., Rhodes, A. M. and Vandemark, J. S. (1975). Observations on pumpkin pollination in Illinois. *American J. Bee.* **115** (1): 139-140.

Judson, J. E. (1929). Morphology and vascular anatomy of the pistillate flowers of the cucumber. *American J. Bot*., **16**: 69-89.

Kamler, F. and Tronickova, E. (1982). Nectar production of different genotypes of cucumber, *Cucumis sativus*. Zapylanie roslin Warzywnych. 111 Seminarium, 113-134.

Kapilm, R. P. and Brar, H. S. (1971). Foraging behaviour of *Apis florae* F. in relation to *Brassica compestris* var toria. Proceedings of XXII International Apicultural Congress, Moscow, pp 335-339.

Kato, E. C. and Couto, R. H. N. (2002). Pollination of winter melon and net melon, *Cucumis melo L.* Naturalia, **27**: 201-210.

Kato, E. C. and Couto, R. H. N. (2002). Pollination of winter melon and net melon, *Cucumis melo L*. Naturalia. **27**: 201-210.

Kauffeld, N. M. and Williams, P. H. (1972). Honey bees as pollinators of pickling cucumbers in Wisconsin. *American J. Botany*.**112**: 252-254.

Kauffeld, N. M., Hernandez, T., Wright, J. and Misaraca, S. (1975). Cucumber production in Louisiana with honey bees as pollinators. *American J. Bee.* **115**(3): 94-95.

Kauffeld, N. M., Hernandez, T., Wright, J. and Misaraca, S. (1978). Insect collected from cucumber plants during a pollination study. *Georgia J. Entomol. Soc*. **13**(1): 67-71.

Kaziev, I. P. and Seidova, S. S. (1965). The nectar yield of flowers of some cucurbitaceae under Azerbaidjan conditions. 20th International Beekeeping Jubilee Congress. 2:31.

Kochetov, A. S. and Cherevko, Y. A. (1977). Biology of flowering and bee pollination in cucumber under plastic in the Yakut ASSR. *Doklady TSKha*. **231**: 169-172.

Kropacova, S. and Nedbalova, V. (1974). Relationship between the honey bees and cucumber. *Acta Universitalis Agriculturae Brno Facultas Agronomica***. 22**(1):101-109.

Lemasson, M. (1987). Contribution of the honey bees to the pollination ofgreenhouse grown plants of gherkin, melon and tomato. *Revue de l' Agriculture.* **40**(4):915-924.

Lord, W. G. (1985). Successful cucumber production will continue to depend on honey bees in the near future. *American J. Bee.* **125:** 623-625

Malerbo, S. D. T., Tadeu, A. M., Bettini, P. C. and Toledo, V. De. (1999). Importance of insects in watermelon (*Citrullus lanatus* Thumb.) (Cucubitaceae). *Acta Scientiarum* **21(3):** 579-583

Mann, L. K. (1953). Honey bee activity in relation to pollination and fruit set in cantaloupe (*Cucumis melo*). *American J. Bot.***40**(7): 545-543.

Martin, E. C. (1970). The use of honey bees in the production of hybrid cucumbers for mechanical harvest. Report, IX Pollination Conference, Arkansas, pp 106-109.

McGregor, S. E. (1976). Insect pollination of cultivated crops. U.S. Department of Agriculture, Agriculture Handbook 496p.

McGregor, S. E. and Todd, F. E. (1952). Cantaloupe production with honey bees. *Econ. J. Entomol.* **45**(1): 43-47.

Motes, J. E. (1977). Pickling cucumbers: production harvesting. Michigan State University Extension Bulletin, E-837.

Mouzin, T. E., Reed, D. K. and Chaney, W. E. (1980). Influence of honey bees on cantaloupe production in Indiana. *Proceedings of Indiana Academy Sciences* **89**: 215-217.

Munger, H. M. (1988). A revision on controlled pollination of cucumber. Report, Cucurbit Genetics Cooperative, U.S.A 11: 8

Musiiko, A. S. (1941). Supplementary artificial pollination of crops. Lenin academy of agricultural sciences, Moscow,18p.

Nandpuri, K. S. and Brar, J. S. (1966). Studies on floral biology in muskmelon (*Cucumis melo L.*). *Ludhiana J. Res.***3**: 395-399.

Nath, P. and Vashistha, R. N. (1969). Studies on vegetative growth, flowering pattern, fruit set and development in Citrullus lanatus Thumb. *Indian J. Hort*. **26**: 51-58.

Nemirovich-Denchenko, E. N. (1964). Concerning the nectar yield and floral biology of cucumbers. lzv. Tombsk. Otd. *Vses. Bot. obshch*. **5**: I27-132.

Nepi, M., Pacini, E. and Willemse, M. T. M. (1996). Nectary biology of *Cucurbita pepo*: ecophysiological aspects. *Acta Botanica Neerlandica* **45**(1): 41-54.

Njoroge, G. N., Gemmill, B., Bussmann, R., Newton, L. E. and Ngumi, V. W. (2004). Pollination ecology of Citrullus lanatus at Yatta, Kenya. *Int. J. Tropical Insect Sci.* **24** (1): 73-77.

Obhayashi, N. (1976). Studies on the proportions and use of pollinators in watermelon growing. *Bulletin of the Kangawa Horticultural Experimental Station.* **23**: 49-53.

Pinzauti, M. (1986). The influence of the wind on nectar secretion from melon and on the flight of bees: the use of an artificial wind break. Apidologia. **17**: 63-72.

Prakash, K. B., Sajjanar, S. M., Kuberappa, G., Prabhuswamy, H. P. and Eswarappa, G. (2004). Effect of number of bee visits on fruit set and some fruit characters in *Cucumis sativus* L. *Advances in Pollen Spore Research*. **22**: 127-130.

Probunkov, V. V. (1977). Habitat nectar productivity and seed yield of red clover. *Nauki*. **3**: 39-43.

Radchenko, T. G. (1964). The importance of pollination on the crop and quality of seed of winter rape. *Bdzhil ' nitstovo*. **1**(1): 68-74.

Rafiq, A. (1992). Effect of honey bee pollination on fruit yield of cucumber crop. *Pakistan J. Zool*. **24**(1): 88-90.

Rana, R. S., Rana, B. S. and Joshi, A. K. (2006). Pollinators fauna in *Cucumis sativus* L., and their effect on seed productivity in Solan district of Himachal PradeshIn: National Seminar on sustainable Beekeeping Development and Honey Festival, 36p.

Rao, G. M. and Suryanarayana, M. C. (1988). Studies on the pollination of watermelon Citrullus lanatus (Thumb.) *Indian J. Bee*. **50**: 5-8.

Rapp, R. (1981). The effect of pollination by honey bees on cucumber cv.'Delila' Seed Production. M.Sc. Thesis, Hebrew University of Jerusalem, Rehovot, Israel, 71 p.

Rashid, M.M. (1999). Sabgi Biggan (in Bangla). Rashid Publishing House, Dhaka. p. 303.

Reshma J., Alam, N., Hossain, M.K. (2011). Variability and correlation studies in short cucumber (*Cucumis sativus* L.). *Jahangirnagar University J. Biol. Sci.* **23**(2): 33-37.

Roberts, R. B. (1979). Spectrophotometric analysis of sugar production by plants and harvested by insects. *Apic. J. Res.***18**: 191-195.

Robinson, R. W. and Hefferman, D. F. (1980). Pollen receptivity of different areas of the stigma in cucumber. Report, Cucurbit Genetics Cooperative, No. 3, 25p.

Rust, R. W., Vaissiera, B. E. and Westrich, P. (2003). Pollination biodiversity and floral resource use in Ecballium elaterium (Cucurbitaceae), *Mediterranean endemic. Apidology*. **34**(1): 29-42.

Safarajan, I. M. (1966). The effect of age of stigma and pollen on fertilization in watermelons. Sborn. Nauc. Trud. Nauc. Issled. Inst. Zemled. *Arm. SSR.* 143-149.

Sajjanar, S. M. and Kuberappa, G. C. (2005). Nectar secretion and sugar concentration in cucumber flowers. *Mysore J. Agri. Sci* **39**(3): 431-432.

Sajjanar, S. M., Kuberappa, G. C. and Prabhuswamy, H. P. (2004). Insect visitors of cucumber (*Cucumis sativus* L.) and the role of honey bee *Apis cerana* F., in its pollination. Pest Management and *Econo. Zool.* **12**(1): 23-31.

Sakamori, M., Yabe, K. and Osuka, M. (1977). Growing muskmelon with honey bees. Research Bulletin of Aichiken Agricultural Research Centre, B Horticulture. **9**: 15-21.

Sanduleac, E. V. (1959). Data on the entomophilous pollination and selection of cucurbitaceae. Lucr. Sti. Stat. *Cent. Seri. Apic.***1**: 129-132.

Sarehane, M. (1994). Effects of honey bees (*Apis mellifira* L.) on several quality criteria of melon (*Cucumis melo L.*) fruits. Proceedings of an international symposium held at Agadir, Morocco, 16-21 January 1994, pp 48-50.

Seshadri, V. S. (1986). Cucurbits. In: Vegetable crops of India. Naya Prakash, Calcutta, pp 91-164.

Sevgican, A. (1976). The effect of pollination on the quality and earliness of green house cucumbers. Sera. hiyaryetistiriciliginde. tozlasmaya yardi-min erkencilik ve &dire Uzerine eddleri Uniersitesi Zirat Fakultest. *Dergisi*.13(3): 265-268.

Seyman, W. S., Barnett, W. W. and Thorp, R. W. (1969). Bee pollination in cucumbers for pickling. *California Agri*. **23**(1): 12-14.

Shakti, C. I., Kumar, J. and Arya, P. S. (1990). Pollination and seed setting studies in cucumber (*Cucumis sativus* L.). *Veg. Sci*. **7**(1):99-101.

Sharma, R. K., Bhardwaj, N. R., Pathania, N., Chandel, R. S. and Joshi, A. K. (2005). Hybrid seed production of cucumber KH-1 and maintenance of seed parent. Seed technology and production centre, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Shaw, F. R. (1953). The sugar concentration of the nectar of some New England honey plants. *Gleanings in Bee Culture*. **81**: 88-89.

Shemetkov, M. F. (1957). The use of bees for pollinating cucumbers in hot houses and forcing beds. Biul. Nauch. Tekh. *Inf. Inst. Pchelovod***2**: 21-24.

Shemetkov, M. F. (1960). Pollinating activity of bees in greenhouses. *Pchelovodstvo*. **37**(1): 28-31.

Shuel, R. W. (1961). Influence of reproductive organs on the secretion of sugars in flowers of Streptosolaniomesonii Miers. *Plant Physiology* **36***:*265-271

Singh, N. P., Bhardwaj, A. K., Kumar, A. and Singh, K. M. (2004). Cucurbits or vine crops. In: Modern technology on vegetable production. International Book Distribution Co. Lucknow, pp 228-234.

Skrebtsova, N. D. (1964). Use of pollinating activity of honey bees for developing hybrid vegetable seed. *Trud. Nauch Issled. Inst. Pchelovod. Selsk. Khoz. Rybnoe*. pp 223-245.

Stambera, J. (1962). Increasing seed production of glass house cucumber by using insect pollinators. *Arch. Gartenb.***10**: 246-256.

Stanghellini, M. S., Ambrose, J. T. and Schultheis, J. R. (1997). The effect of honey bee and bumble bee pollination on fruit set and abortion of cucumber and watermelon. *American J. Bee.***137**(5): 386-391.

Stanghellini, M. S., Ambrose, J. T. and Schultheis, J. R. (1998). Using commercial bumble bee colonies as backup pollinators for honey bees to produce cucumber and watermelons. *Horticultural Technology* **8**(4): 590-594.

Stanghellini, M. S., Ambrose, J. T. and Schultheis. J. R. (2002). Diurnal activity, floral visitation and pollen deposition by honey bees and bumble bees on field grown cucumber and watermelon. *Apic. J. Res*. **41**(1/2): 27-34.

Steinhauer, A. L. (1970). Honey bee pollination of cucumbers in Maryland. *American J. Bee.***110**: 12-13.

Stephan, W. A. (1970). Honey bees for cucumber pollination. *American J. Bee*. **110**(1): 132-133.

Tarbaeva, L. P. (1960). The biology of flowering and pollination in the Altej melon. *Bjull. Glay. Bot. Sada.***38**: 76-78

Tepedino, V.I. (1981). The pollination efficiency of squash bee (*Peponapis pruinosa*) and the honey bee (*Apis mellifera*) on summer squash (*Cucurbita pepo*). Kansas J. Ento. Soc.**54**(2): 359-377.

Tew and Carron. (1988). Fruit crops. Ohio State Research Circular 295: 38-41.

Tatlioglu, T. (1993). Genetic Improvement of Vegetable Crops. Kalloo, G. and B.O. Beorgh (eds.). Pergamon Press, Oxford. pp. 197-233.

Tsyganov, S. K. (1953). Remarks on the pollinating activities of honey bees. *Uzbek. Akad. Nauk. Inst. Zool i Parasitol.Trud*. 91-122.

Tuljzenkova, F. F. (1955). The effects of pollination by bees on yield of cucumbers grown under cover in the far North. Sadi Ogord**. 4**: 24-25.

Van, W. E. (1993). Cucumber yield response to plant density and spatial arrangement. *Production J. Agric.* **6**:253-255.

Williams, P. (1987). Pollination of melons. *Australian J. Bee.* **68**(7): 18-21.

Wolf, S., Lensky, Y. and Paldi, N. (1999). Genetic variability in flower attractiveness to honey bees (*Apis mellifera*) within the genus *Citrullus*. *Hort. Sci.* **34**(5): 860-863.

Woyke, H. W. and Brownikowska, K. (1984). The influence of honey bee population on pickling cucumber yield. Proceedings of the 5th international symposium on pollination, Versailles. pp 323-327.

CHAPTER VII

ANNEXURE

Appendix 1. Multiple Range Test for relative abundance of insect visitors per 10 minutes per m^2

Method: 95.0 percent LSD

Contrast	Sig.	Difference	+/- Limits
A_ cerana - A_ dorsata		-1.036	3.03987
A_ cerana - A_ florea		-0.086	3.03987
A_ cerana - A_ mellifera		-1.15	3.03987
A_ cerana - Formica sp_	*	**-8.642**	3.03987
A_ cerana - Halictus sp_		-0.308	3.03987
A_ cerana - Syrphids		0.248	3.03987
A_ dorsata - A_ florea		0.95	3.03987
A_ dorsata - A_ mellifera		-0.114	3.03987
A_ dorsata - Formica sp_	*	**-7.606**	3.03987
A_ dorsata - Halictus sp_		0.728	3.03987
A_ dorsata - Syrphids		1.284	3.03987
A_ florea - A_ mellifera		-1.064	3.03987
A_ florea - Formica sp_	*	**-8.556**	3.03987
A_ florea - Halictus sp_		-0.222	3.03987
A_ florea - Syrphids		0.334	3.03987
A_ mellifera - Formica sp_	*	**-7.492**	3.03987
A_ mellifera - Halictus sp_		0.842	3.03987
A_ mellifera - Syrphids		1.398	3.03987
Formica sp_ - Halictus sp_	*	**8.334**	3.03987
Formica sp_ - Syrphids	*	**8.89**	3.03987
Halictus sp_ - Syrphids		0.556	3.03987

* denotes a statistically significant difference.

Appendix 2. Multiple Range Test for effect of different modes of pollination on fruit size (cm) and 1000-seed weight.

Multiple Range Test:

Contrast	Sig.	Difference	+/- Limits
Hand - Open		0.47	1.85673
Hand - Without Honeybee	*	**4.53333**	1.85673
Open - Without Honeybee	*	**4.06333**	1.85673

* denotes a statistically significant difference.